MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2015/2016

DET5038 – POWER ELECTRONICS
(Diploma in Electronics Engineering)

9 MARCH 2016
2:30 p.m – 4:30 p.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This booklet consists of 7 pages with **5 questions** only excluding the cover and the appendix.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the answer booklet provided. All necessary working **MUST** be shown in the answer booklet.

QUESTION 1 [20 marks]

(a) State the 4 characteristics of an ideal controllable switch.

(4 marks)

(b) Explain the reasons behind the preference of an NPN BJT compare to a PNP BJT design.

(3 marks)

(c) Draw the Forward Biased Safe Operating Area (SOA) of a MOSFET. State and label the 4 boundary limits in the SOA diagram.

(7 marks)

(d) Figure 1 show a full wave rectifier with a resistive load. It uses 4 identical power diodes which each of them gives R_{on} = 0.2Ω and V_{th} = 0.7 V with the peak current across the load is 20A, calculate the power loss in each of the diode.

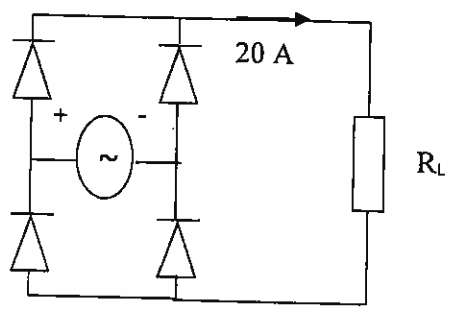


Figure 1

(6 marks)

Continued ....

QUESTION 2 [20 marks]

(a) Define the process of commutation.

(2 marks)

(b) Figure 2 shows a type of rectifier. Draw the input and output waveform for the rectifier circuit covering the $V_S(t)$, $i(t)$, $V_R(t)$, and $V_{diode}(t)$.

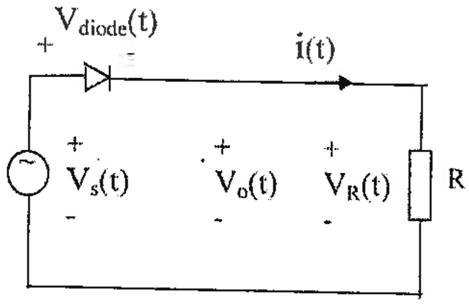


Figure 2

(8 marks)

(c) A 150 Ω load resistor is connected to a circuit consisting of a **single phase full wave** uncontrolled rectifier. A power supply operated at 240 V, 50 Hz is used to supply input voltage to the rectifier circuit.

(i) Calculate the average output voltage.

(2 marks)

(ii) Determine the RMS output voltage.

(2 marks)

(iii) Estimate the ripple voltage.

(2 marks)

(iv) Find the ripple voltage factor.

(2 marks)

(v) Compute the average output current.

(2 marks)

Continued ....

QUESTION 3 [20 marks]

(a) Draw the schematic diagram of a Buck-Boost DC-DC Converter. State its main advantage over the normal Buck Converter and Boost Converter.

(8 marks)

(b) A converter is operating from 20 V DC voltage source and its supply 10.2 W across a 800 Ω load resistor under continuous conduction mode at the frequency of 5 kHz. Assume that the filter capacitance is very large and neglect the ON state voltage drop across the diode. Compute for the following:

(i) The output voltage and duty ratio.

(4 marks)

(ii) The type of this converter. Justify your answer.

(2 marks)

(iii) The minimum inductance value needed for this converter.

(3 marks)

(iv) The output ripples voltage produced by 18μF capacitor.

(3 marks)

Continued ....

QUESTION 4 [20 marks]

(a) Figure 4(a) shows a single phase half bridge inverter.

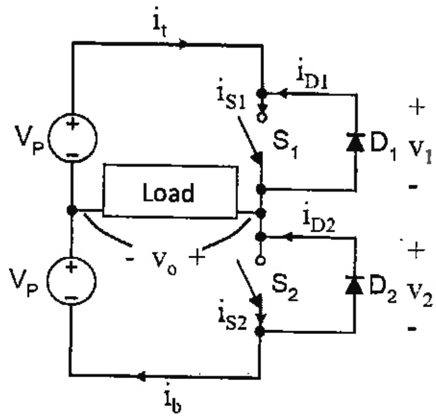


Figure 4(a)

Draw the output load current waveform if the load is replaced by :

(i) Resistor (2 marks)

(ii) Inductor (2 marks)

(iii) Resistor in series with an inductor (2 marks)

Continued ....

(b) In a laboratory experiment, a full-bridge inverter is operated by a 120V DC power supply between the point P and Q in Figure 4(b). The inverter frequency is tune to be 2 kHz which is operating at a duty cycle of 80%. Calculate the following:

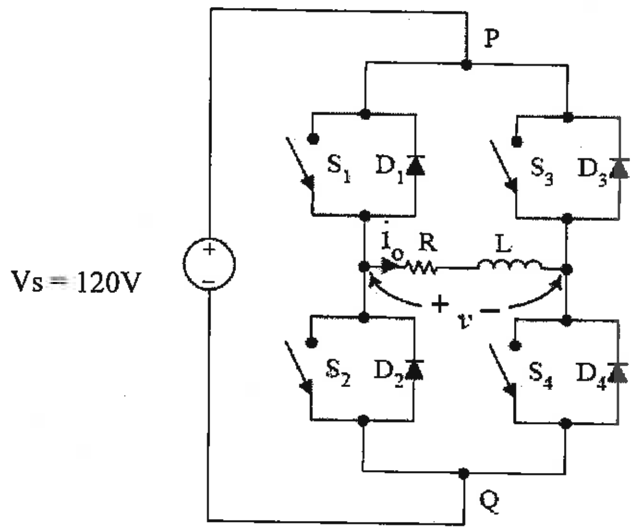


Figure 4(b)

(i) RMS value of the total output voltage.

(2 marks)

(ii) RMS output voltage of the fundamental component in radian, given

$$V_{1,rms} = 0.9V_S \sin\frac{D\pi}{2}$$

(2 marks)

(iii) RMS output voltage of total harmonic component, given:

$$V_{H,rms} = \sqrt{DV_S^2 - \frac{8V_S^2}{\pi^2}\sin^2\tfrac{1}{2}D\pi}$$

(3 marks)

(iv) Total harmonic distortion.

(3 marks)

(v) Voltage transfer ratio.

(2 marks)

(vi) Harmonic factor of 1st harmonic.

(2 marks)

Continued ....

QUESTION 5 [20 marks]

(a) Define a resonant converter.

(2 marks)

(b) Figure 5(a) shows a series resonant converter.

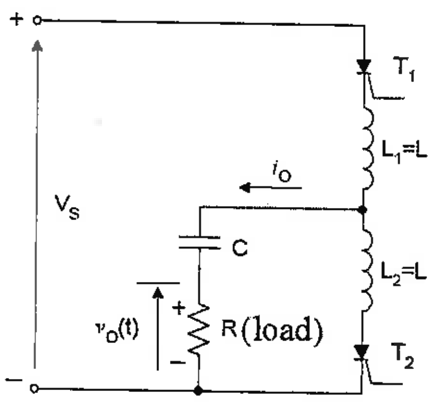


Figure 5(a)

Sketch the equivalent circuit for the mode of operation during:

(i) Mode 1: When only T1 is triggered. (2 marks)

(ii) Mode 2: When both T1 and T2 are OFF. (2 marks)

(iii) Mode 3: When only T2 is triggered. (2 marks)

Continued ....

(c) Figure 5(b) shows a half bridge resonant converter with a unidirectional switch. It contains a capacitor voltage, V_{C0} = 170V when it is at time equal to zero.

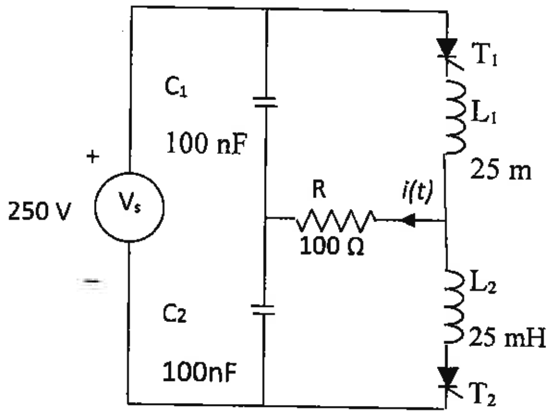


Figure 5(b)

Calculate the following:

(i) Damping factor, α.

(3 marks)

(ii) Angular resonant frequency, ω_o.

(3 marks)

(iii) Angular ringing frequency, ω_r.

(3 marks)

(iv) Instantaneous load current expression, *i(t)*, given

$$i\ (t) = \frac{V_s + V_{C0}}{L\omega_r} e^{-\alpha t} \sin \omega_r t$$

(3 marks)

End of Page.

APPENDIX

Table 1 Switching power loss of power BJT

	Resistive Load	Inductive Load
ON state	$P_{on} = [V_{CE(sat)}I_{C(on)} + V_{BE(on)}I_{B(on)}]\frac{t_{on}}{T}$	$P_{on} = [V_{CE(sat)}I_{C(on)} + V_{BE(on)}I_{B(on)}]\frac{t_{on}}{T}$
OFF state	$P_{off} = [V_{CC}I_{C(leak)}]\frac{t_{off}}{T}$	$P_{off} = [V_{CC}I_{C(leak)}]\frac{t_{off}}{T}$
Turn On	$P_{turn-on} = V_{CC}I_{C(on)}\frac{\tau_{on}}{6T}$	$P_{turn-on} = V_{CC}I_{C(on)}\frac{\tau_{on}}{2T}$
Turn Off	$P_{turn-off} = V_{CC}I_{C(on)}\frac{\tau_{off}}{6T}$	$P_{turn-off} = V_{CC}I_{C(on)}\frac{\tau_{off}}{2T}$

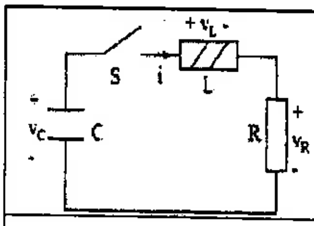
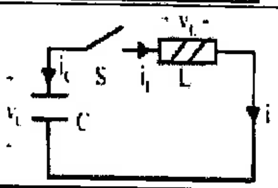
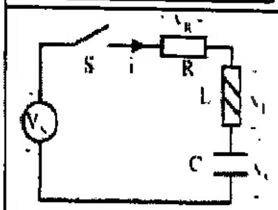
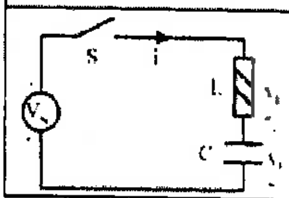
Table 2 Switching power loss of power MOSFET

	Resistive Load	Inductive Load
ON state	$P_{on} = I_{D(on)}^2 R_{DS(on)}\frac{t_{on}}{T}$	$P_{on} = I_{D(on)}^2 R_{DS(on)}\frac{t_{on}}{T}$
OFF state	$P_{off} = I_{D(off)}V_{DD}\frac{t_{off}}{T}$	$P_{off} = I_{D(off)}V_{DD}\frac{t_{off}}{T}$
Turn On	$P_{turn-on} = \frac{V_{DD}I_{D(on)}\tau_{on}}{6T}$	$P_{turn-on} = \frac{V_{DD}I_{D(on)}\tau_{on}}{2T}$
Turn Off	$P_{turn-off} = \frac{V_{DD}I_{D(on)}\tau_{off}}{6T}$	$P_{turn-off} = \frac{V_{DD}I_{D(on)}\tau_{off}}{2T}$

Table 3 Useful equations of DC to DC converters

Buck Converter	Boost Converter	Buck-Boost Converter
$V_o = DV_s$	$D = 1 - \frac{V_s}{V_o}$	$D = \frac{V_O}{V_s + V_O}$
$I_L = \frac{V_o}{R}$ $(\Delta i_L)_{close} = \frac{V_s - V_o}{L} DT$ $(\Delta i_L)_{open} = -\frac{V_o}{L}(1-D)T$	$I_L = \frac{V_s}{R(1-D)^2}$ $(\Delta i_L)_{close} = \frac{V_s}{L} DT$ $(\Delta i_L)_{open} = \frac{V_S - V_o}{L}(1-D)T$	$I_L = \frac{V_s D}{R(1-D)^2}$ $(\Delta i_L)_{close} = \frac{V_S}{L} DT$ $(\Delta i_L)_{open} = -\frac{V_o}{L}(1-D)T$
$L = \frac{(1-D)R}{2f}$	$L = \frac{D(1-D)^2 R}{2f}$	$L = \frac{(1-D)^2 R}{2f}$
$C_{min} = \frac{1-D}{8Lf^2 \frac{\Delta V_o}{V_o}}$	$C = \frac{D}{Rf \frac{\Delta V_o}{V_o}}$	$C = \frac{D}{Rf \frac{\Delta V_o}{V_o}}$

Table 4 Current (i) and capacitor voltage (V_c) expressions for resonant circuits.

	$i = \frac{V_0}{\omega_r L} e^{-\alpha t} \sin \omega_r t$ $V_c = V_0 e^{-\alpha t}\left[(\alpha / \omega_r)\sin(\omega_r t) + \cos(\omega_r t)\right]$
	$i = \frac{V_0}{\omega_o L} \sin \omega_o t$ $V_c = V_0 \cos \omega_o t$
	$i = \frac{V_s - V_0}{L\omega_r} e^{-\alpha t} \sin \omega_r t$ $V_C = -(V_S + V_0)e^{-\alpha t}\left[\frac{\alpha}{\omega_r}\sin \omega_r t + \cos \omega_r t\right] - V_0$
	$i = \frac{V_S - V_O}{Z_O} \sin \omega_O t$ $V_C = V_S - (V_S - V_O)\cos \omega_O t$